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Solar water heating initiative in Oman energy saving and carbon credits

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ABSTRACT

By the virtue of its position astride the tropic of cancer, Oman has an important potential of solar energy. Despite these important resources the uses of this renewable energy was limited to few and simple utilization as public lighting or park meter. Recently, the renewable energy sector in Oman is considered as a national priority to supply the future energy demand. This paper investigates the potential of solar water heater application in Oman through a preliminary case study in the Seeb district. The RETScreen Clean Energy Project Analysis Software is an advanced mathematical model to evaluate the energy production and savings costs, emission reductions, financial viability and risk for various types of Renewable-energy and Energy-efficient Technologies. This preliminary study shows that this renewable energy technology has eco-environmental benefits to Oman. The dissemination of the solar water heaters in Oman requires necessarily the contribution of the Government in order to make them. Instead of paying subsidies for the electricity consumed by electric water heaters, the Government can invest in sharing half of the capital cost. The clean development mechanism could help to foster the diffusion of the SWHs in Oman by providing certified emission reduction incentives to the Government.

Contents

1. Introduction

Techniques for harnessing energy from the sun for water heating have been commercially available since the 1800s. Development of the solar water heaters (SWHs) has mainly concentrated on how they look like and the types of material they use. The purpose of using sun radiations to heat water instead of a combustible source or power plant-produced electricity is to lessen the amount of pollutants introduced into the environment and atmosphere.

Geographic location, system design, collector orientation, and collector size will determine how much energy can be provided for domestic hot water heating. It has been demonstrated in [1] that Oman is blessed with a huge amount of solar energy which can serve many purposes. Solar energy in Oman can meet all of domestic hot waters' needs.

The household sector is the largest consumer of electricity in Oman. According to the 2008 annual report of Authority for Electricity Regulations [2], the residential customers consume around 54.7% of the total electricity supplied to customers. It is known that air-conditioning is the highest load consumption; however, electric water heating is also a major electric energy consumer. Water heating in Oman may account for approximately 20–25% of the total electric energy used in a typical single-family home. An elec-

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tric water heater is the single biggest energy user of all appliances in the home after air conditioners.

SWH can be used in any climate, and the fuel they use (sunshine) is free. However, solar water heating systems may require periodic maintenance and have a relatively high initial cost. The payback period however is different depending on the cost of energy for heating water and the incentives used by governments. In areas like Oman, where electricity is used for water heating, the payback periods are expected to be shorter than for areas that use natural gas for water heating.

By replacing electric energy or fossil fuel use for water heating with solar energy, environmental carbon emissions associated with water heating are reduced or eliminated. SWHs became relevant for the Clean Development Mechanism (CDM) because they are implicated directly in the reduction of GHG while contributing to the sustainable development. Purohit and Michaelowa [3] undertook a detailed study about the potential of the CDM for the SWHs usage in India. The study indicates that there is a vast theoretical potential of CO_2 mitigation by the use of Solar Water Heater in India. The annual Certified Emissions Reductions (CERs) potential of Solar Water heaters in India could theoretically reach 27 million tones. According to Capacity Development for the CDM [4], presently, there are already 3 SWHs projects (all in India) which were approved by the executive board of the CD4CDM.

Several countries have put in place incentive programs to support the cost of installing renewable energy systems. In 2005, Spain became the first country in the world to require the installation of photovoltaic electricity generation in new buildings, and the second to require the installation of solar water heating systems in 2006 [5]. Australia adopted the mandatory regulation for solar thermal for new construction in 2006 as well. SWH systems have become popular in China, where basic models start at around US$190, much cheaper than in Western countries (around 80% cheaper for a given size of collector). It is believed that at least 30 million Chinese households now have one solar water heater, and that the popularity is due to the efficient evacuated tubes which allow the heaters to function even under gray skies and at temperatures well below freezing [6].

However, most of countries in the Gulf region have not yet adopted any policy to encourage the usage of SWH. This is due to the highly subsidized cost of fossil fuel energy for electricity production [7].

This paper demonstrates the benefits of using SWH in Oman through a case study application to the Seeb district. The study was conducted using the RETScreen software. Section 2 presents the technologies of SWHs and the performances of the SWHs. Section 3 describes the application of the RETScreen software for the analysis of the SWHs system. Section 4 considers a case study application for the Seeb district and presents the results obtained. Section 5 highlights the CDM potential of SWHs in the Seeb district. Section 6 concludes the paper.

2. Solar water heater technologies

SWHs can be used for domestic hot water, pool heating and also space heating needs. SWH systems include storage tanks and solar collectors. A typical domestic SWH system diagram is shown in Fig. 1. There are two types of solar water heating systems: active (forced circulation), which have circulating pumps and controls, and passive, which do not.

In warm countries, such as Oman, a passive water heater is considered a suitable option. It consists of a water tank integrated into or located above a solar collector. In an integrated collector storage system, also called batch water heater, the water is heated and stored inside the collector.

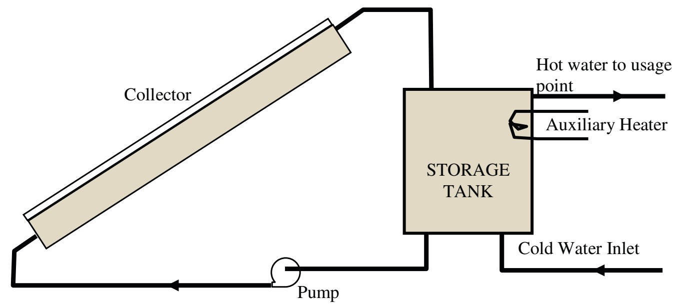

Fig. 1. Diagram of a solar active SWH system.

There are several types of solar collectors. Most of them are roof-mounted and consist of a flat copper plate, painted black, which has water tubes attached to the absorber plate. The solar radiation (energy) falls on is absorbed by the copper plate. The heat energy is transferred to water flowing in the tubes. The absorber plate is mounted in an adequate casing with a clear covering and insulation to protect the absorber plate from losses of heat energy. Other collectors include also an integrated collector and storage system and the evacuated tube collector. Integral collector and storage systems combine the function of hot water storage and solar energy collection into one unit. Evacuated tube collectors produce higher temperature water and are more complex than flat plate collectors. Evacuated tube collectors consist of a series of tubes that contain a heat pipe which absorb solar energy and transfer it to a liquid medium. The tubes are evacuated (vacuum) so that there is very little heat loss from the tube.

The energy performance of SWH system is influenced by a number of environmental and technical factors. For instance, these factors may include energy resource such as the amount of solar radiation hitting the solar collectors, and design elements such as the collector type (e.g. glazed, unglazed or evacuated tubes), area and efficiency, as well as the solar tracking mode (i.e. fixed, one-axis, azimuth or two-axis tracker), the slope and the azimuth (physical orientation) of the solar water heater. Other factors may include the required end-use water temperature and the supply temperature of the water available.

The performance of service hot water systems with storage is estimated with the *f-Chart* method. The method is explained in detail in Chapter 20 of [8] and summarized in RETScreen Engineering and Case Studies Textbook, Solar Water Heating Analysis Project Chapter [9]. The purpose of the method is to calculate f, the fraction of the hot water load that is provided by the solar heating system (solar fraction). Once f is calculated, the amount of renewable energy that displaces conventional energy for water heating can be determined.

3. RETScreen software application

The RETScreen Software Solar Water Heating Project Model is used to evaluate the energy production and savings, costs, emission reductions, financial viability and risk for the SWH project in Seeb region. The software was designed for projects ranging in size from solar collectors for small-scale domestic hot water applications, for indoor and outdoor swimming pools for residential, commercial and institutional buildings, and for large-scale industrial processes and aquaculture applications, to improved water heating system designs including solar collector installation, hot water temperature and use reduction, and improved pipe insulation [10].

The software contains a database of typical daily hot water use for loads such as houses, apartments, hotels and motels, hospitals, offices, restaurants, schools, laundry rooms and car washes. The Energy Model and Solar Resource & Heating Load worksheets are

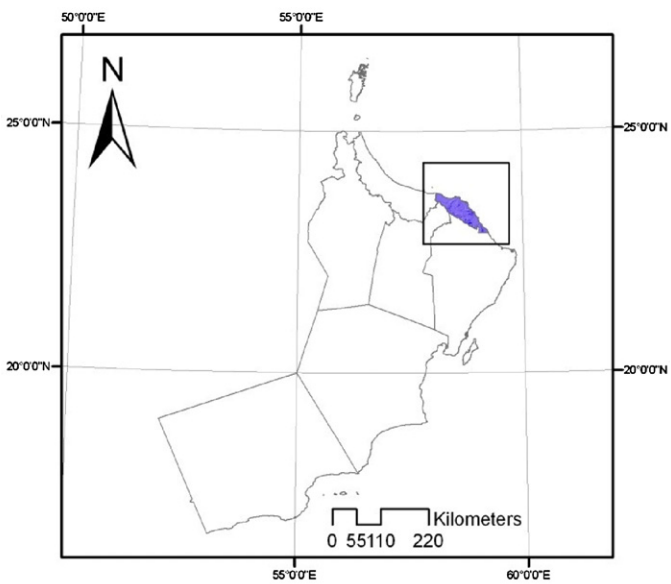

Fig. 2. Localization of the study area.

completed first. The Cost Analysis worksheet is then completed, followed by the Financial Summary worksheet. The GHG Analysis and Sensitivity worksheets are optional analyses but were selected and used in this project. The GHG Analysis helps estimate the greenhouse gas (GHG) mitigation potential of the proposed project. The Sensitivity worksheet helps estimate the sensitivity of important financial indicators in relation to key technical and financial parameters. This process is repeated several times in order to optimize the design of the solar water heating project from an energy use and cost standpoints.

4. Case study

To highlight the benefits of using SWHs in Oman, a case study was considered.

4.1. Selected region and its parameters

The selected region for the investigation is the Seeb district. The Seeb district is situated in the North West part of Muscat urban area 23°30′N to 23°43′N and 58°19′E to 58°50′E) (Fig. 2).

An energy model was developed for a typical house in the Seeb district using the RETScreen Software. The weather data used by the software is given in Table 1. It is based on the observations measured at the Muscat International Airport which is very close to the selected region under investigation.

Table 2
RETScreen energy model input parameters for the basic scenario model 1.

Parameter	Value
Average number of people per house	4
Occupancy rate (%)	90
Daily hot water usage estimate (L/day)	220
Hot water temperature (°C)	50
Operating days per week	7
Supply water minimum temperature (°C)	10
Supply water maximum temperature (°C)	33
Solar water heater type	Glazed
Gross area per solar collector (m^2)	2.96
Aperture area per solar collector (m^2)	2.78
Fr (tau alpha) coefficient	0.64
Fr UL coefficient	4.65
Number of collectors	1
Capacity (kW)	1.95
Initial cost (US$)	2000
Miscellaneous losses	3%
Storage capacity per square meter (L/m^2)	80
Conventional fuel type	Electricity
Seasonable efficacy (%)	60
Electricity rate ($)	0.026 (subsidized rate, actual cost is the double)
Inflation rate (%)	3
Project life (years)	25
Debt ratio (% of initial cost)	0
Initial grant (% of initial cost)	50
Annual O&M cost (US$)	20
GHG emission factor for natural gas (tCO_2/MWh)	0.780

The parameters of the basic scenario are listed in Table 2. This basic scenario considers a typical house with 4 occupants situated at the Seeb region baring alone the full initial cost of the SWH purchase and installation. Other scenarios can also be developed for houses with bigger number of occupants and for different grants/incentives offered by the Government during the purchase and installation of the SWH.

4.2. RETScreen results analysis for a typical household

The cumulative cash flow analysis result, produced by RETScreen for the basic scenario without incentives and grants, is shown in Fig. 3.

The calculated pre-tax IRR for assets is 5%. The simple and equity payback periods are 19.7 and 15.3 years, respectively. It is clear from these results that the SWH project will not be sufficiently profitable to home owners to encourage them to invest in such a project.

Table 1
Seeb district weather data.

Month	Air temperature (°C)	Relative humidity (%)	Daily solar radiation – horizontal (kWh/m^2/d)	Atmospheric pressure (kPa)	Wind speed at 10 m (m/s)	Earth temperature at 0 m (°C)	Cooling degree–days (°C–d)
January	21.1	63.4	4.0	99.06	2.7	22.89	344.1
February	21.9	62.2	4.7	98.91	2.8	23.55	333.2
March	24.4	59.4	5.5	98.66	2.9	26.21	446.4
April	29.2	47.1	6.3	98.35	2.9	30.01	576
May	34.0	39.8	6.9	97.92	3.2	33.53	744
June	34.8	50.6	6.7	97.39	2.9	35.40	744
July	33.5	62.0	6.1	97.23	3.0	35.41	728.5
August	31.7	68.9	6.0	97.46	2.9	34.57	672.7
September	31.0	65.4	5.8	97.95	2.6	32.92	630
October	29.2	55.9	5.2	98.53	2.5	30.35	595.2
November	25.4	60.5	4.4	98.90	2.4	27.16	462
December	22.6	66.2	3.8	99.10	2.4	24.30	390.6
Annual	28.3	58.4	5.5	98.3	2.8	29.72	6666.7

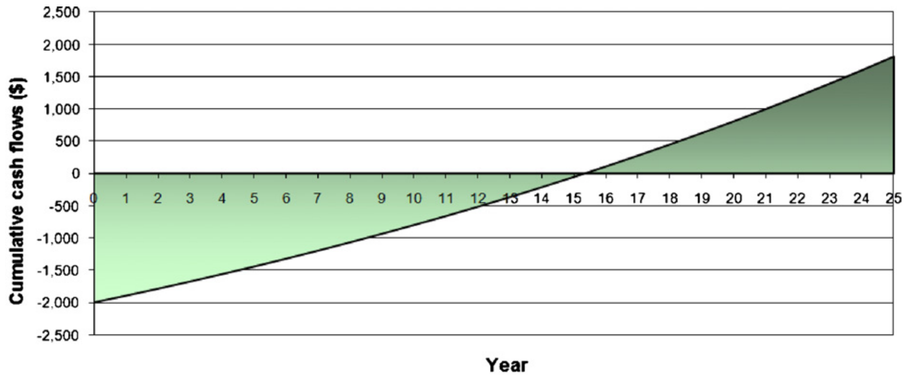

Fig. 3. Cumulative cash flow analysis result for basic scenario.

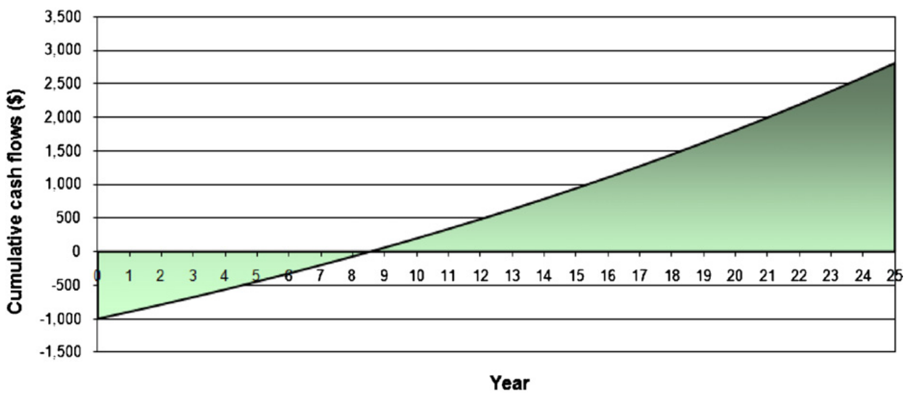

Fig. 4. Cumulative cash flow analysis result for 50% grant scenario.

If an incentive/grant equal to 50% the initial cost is considered, then the calculated pre-tax IRR for assets becomes 12.2% and the simple and equity payback periods become 9.9 and 8.5 years, respectively. The cumulative cash flow analysis result for this scenario is shown in Fig. 4. The annual electricity consumption of such a typical house is 6 MWh/year.

The other important gain for the Government is the reduction of CO_2 footprint. In this case study, the net annual GHG emission per house is reduced by 3.6 tCO_2 which is equivalent to 8.5 barrels of crude oil not consumed. This might seem negligible for one house but it may become very important when thousands of houses are considered as demonstrated below.

In Oman, the electricity rate is subsidized by the Government and reaches up to 100% the rate paid by the consumers. In the case of Seeb district which is stated in Muscat region, the Government pays about US$ 0.026 per kWh. Therefore, if the house owner pays 50% and the Government pays the other 50% of the initial SWH cost, the Government will achieve the same benefits and return rates as the home owner. This means that the investment made by the Government through giving incentives and grants will be also profitable to the Government since both the home owners and the Government would have very similar IRR and payback periods.

Since family sizes in Oman range from medium to large families, it is important to analyze some SWH project scenarios for different family sizes. Results of this analysis are given in Table 3.

Notice that the higher the number of occupants per house the better the benefits of implementing the SWH systems. These results will be used hereafter for analyzing the Seeb district total domestic SWHs project.

4.3. Generalized analysis to all Seeb district

The total urban area in the Seeb district is about 52 km^2 with a total population around 221,115 inhabitants composed of 30,709 families and total households about 34,062 units distributed as shown in Fig. 5. The average family size in this district ranges between 4 and 12 people per family (house).

Table 3
Variation of results as a function of the number of house occupants.

Number of occupants	Number of panels	Initial cost ($)	IRR (%)	Simple payback (yr)	Equity payback (yr)	Annual energy (MWh)	Annual GHG emission reduction (tCO_2)	Equivalent in oil barrels
4	1	2000	12.2	9.9	8.5	6.0	3.6	8.5
5	1	2200	13.0	9.3	8.1	7.4	4.2	9.7
6	1	2400	13.4	9.0	7.9	8.7	4.6	10.7
7	1	2600	13.9	8.7	7.6	10.4	5.1	11.8
8	1	2800	14.0	8.6	7.6	11.7	5.5	12.7
9	1	3000	14.2	8.5	7.5	13.4	5.9	13.7
10	1	3200	14.2	8.2	7.5	14.7	6.2	14.5
11	2	4000	16.5	7.3	6.5	16.4	8.8	20.6
12	2	4200	16.5	7.3	6.5	17.7	9.3	21.6

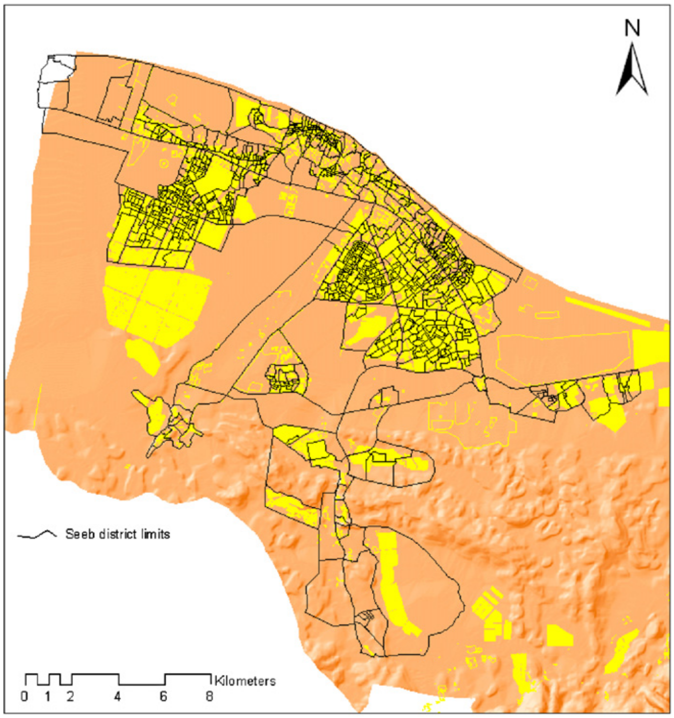

Fig. 5. Seeb district urban areas.

Table 4
Summary of results obtained for the Seeb district case study.

Total annual energy saving (MWh)	Total annual GHG emission reduction (tCO_2)	Total equivalent in oil barrels
335,431	148,590	2,625,374

Seeb district witnessed spectacular urban sprawl in the latest years with very few common households and mainly individual households, which are very suitable for domestic SWH applications. Besides, this urban growth is expected to continue, which will also increase the potential of SWH applications. The study is limited to domestic buildings only and does not include commercial, industrial, and government buildings.

The results of investigating the benefits of using SWHs in the Seeb district are summarized in Table 4.

The Seeb district was divided into 18 sub-districts and agglomerations. Notice that there is a considerable gain in both saving energy and minimizing the GHG emissions, in addition of the profitable investment for both household owners and the Government as demonstrated previously.

5. CDM potential

The Clean Development Mechanism was formulated as part of the Kyoto Protocol in 1997. CDM essentially allows developed nations to purchase carbon credits through approved renewable energy projects in developing countries. Recently, the CDM executive board adopted simplified CDM modalities and procedures for qualifying small-scale projects defined as follows [4]:

(a) renewable energy project activities with a maximum output capacity equivalent of up to 15 MW,
(b) energy efficiency improvement project activities which reduce energy consumption by an amount equivalent to 60 GWh per year, and
(c) other project activities whose emission reductions are less than 60 $ktCO_2$ per year.

It is clear from these criteria and the results obtained in the previous section that the Seeb district SWHs project can be a first good candidate for CDM approval for Oman. In fact, according to the published current CDM pipeline projects [4] none of them is from Oman or the region.

Since in Oman the CDM transaction rate is not yet well defined, and knowing that the current Certified Emission Reduction (CER) prices under CDM is ranging between US$ 5 and 25 [4], we can assume an average of US$ 15 per CER. In this case, according to Table 3, we can estimate the total annual CER volumes around 2.23 millions which are considered very attractive and can be considered sufficient incentives.

6. Conclusions

RETScreen was used to analyze the SWH initiative in Oman through case study for the Seeb district. It was found that the annual energy saving for the Seeb district only is around 335,431 MWh. This is equivalent to the annual energy produced by a 38.3 MW power plant (generators). This means that, by replacing existing electric water heaters with SWHs, it will be possible to develop and expand future industrial applications without a need for constructing additional power plants in the short term.

The economic value of a domestic SWH system resides mainly in the amount of electrical energy it saves in addition to the degree of independence from conventional and polluting energy supplies it creates. In fact, Oman is in the process of constructing a large coal power plant because of the increasing demand for electric energy by its industrial sector. Investing in SWHs in addition to constructing renewable energy power generation facilities would help satisfy the increasing demand in electric power and at the same time will reduce the GHG emission and create additional businesses and jobs.

Without the contribution of the Government in the investment of SWHs systems, the household owners will not find enough incentives to use SWHs in their households. It was found that a 50% sharing of the capital cost between home owners and the Government will benefit both parties and will produce profitable investments. Instead of paying subsidies for the electricity consumed by electric water heaters, the Government can invest in sharing half of the capital cost. It was found that the internal return rate ranges between 12.2 and 16.5% and the simple payback period is between 7 to 10 years which indicate a very good investment project for both householders and the Government.

Finally, it was found that such project has a big chance to qualify as a small-scale project and get approved by the CDM executive board. Therefore, CDM could also be used as an additional tool to foster the dissemination of the SWHs in Oman by providing more incentives for the Government to contribute in the initial investment.

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